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STUDENT REPORT

THE SOVIET STEALTH FIGHTER:
CHECK OR CHECKMATE?

MAJOR STANLEY P. SIEFKE 88-2405

"insights into tomorrow"

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CHECK OR CHECKMATE?

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Stealth technology is a complex science requiring the reduction of characteristic vehicle signatures in the acoustical, optical, infra-red, and radar environments. The use of this technology has far reaching impacts on the defenses an opponent must develop to detect such a vehicle. The Soviets have the doctrine that can use vehicles with this technology. It amplifies their firm commitment to offensive capabilities using elements such as surprise, deception, firepower, and maneuver. They show understanding of the basic principles involved in the design of this type of vehicle. They also have a strong background in the electro-magnetic research and development fields capable of producing radar absorption materials. If all else fails, they definitely have the proven capability to steal it. This study concludes the Soviet Union will probably deploy their own version of the Advanced Tactical Fighter near the turn of the century. The quality of the vehicle is still suspect, but the U.S. must be prepared to handle such an eventuality.

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PREFACE

Subject to clearance, this manuscript will be submitted to Air Power Journal for consideration.

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Major Siefke graduated from the US Air Force Academy in 1975 with a B.S. degree in Aeronautical Engineering. In 1976 he obtained an M.S. degree in Aeronautics and Astronautics from Purdue University. He is currently enrolled in a M.E. degree program in Electrical Engineering from the University of Idaho. Major Siefke attended Squadron Officer School in 1976 and is currently a member of the Class of 1988 at Air Command and Staff College.

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EXECUTIVE SUMMARY

REPORT NUMBER 88-2405

AUTHOR(S) MAJOR STANLEY P. SIEFKE, USAF

TITLE THE SOVIET STEALTH FIGHTER: CHECK OR CHECKMATE?

I. Purpose. To show the Soviet Union intends to develop and deploy systems using low observables (stealth) technology.

II. Problem. As the Department of Defense begins developing stealthy weapon systems, there exists a notion this technological breakthrough will be the panacea for the U.S. defense problems with an adversary who has numerical superiority. However, stealth technology is a capability the Soviets could just as well develop and deploy, greatly compounding our own defense issues.

III. Data. Stealth technology is a complex science requiring the reduction of characteristic vehicle signatures in the acoustical, optical, infra-red and radar environments. The use of this technology has far reaching impacts on the defenses an opponent must develop to detect such a vehicle. The Soviets have the doctrine that can use vehicles with this technology. The use of this type of vehicle dovetails nicely with all aspects of Soviet doctrine. It also amplifies their firm commitment to offensive capabilities using elements such as surprise, deception, firepower and maneuver. There is growing evidence the Soviets are currently d /eloping a foundation for the development and deployment of stealth technology. They show an understanding of the

basic principles involved in the design of this type of vehicle. They also have a strong background in the electro-magnetic research and development fields capable of producing radar absorption materials. If all else fails, they definitely have the proven capability to steal it.

IV. Conclusion. The Soviet Union will probably deploy their own version of the Advanced Tactical Fighter near the turn of the century. The quality of such a vehicle is still suspect; however, if produced in significant numbers, it could prove to be a significant defense issue. The US must be prepared to handle such an eventuality.

Chapter One

INTRODUCTION

The Advanced Tactical Fighter. The Advanced Tactical Aircraft. The Advanced Technology Bomber. The Advanced Cruise Missile. All of these future weapon systems have one thing in common: "stealth" (or low observables) technology. The Department of Defense (DoD) has announced all these weapon systems will employ stealth technology in their basic design to improve their survivability in an increasingly lethal defensive environment. At the same time, however, DoD has clamped down on the security of stealth technology, and for good reason.

A weapon system using low observables technology creates a significant challenge for anyone attempting to defend against it. Dr. Hicks, the Secretary of Defense for Research and Engineering, stated that a mature application of low observables "will have a simple, easily understood effect. It will render Soviet air defenses--defenses in which they have already invested rubles to the tune of more than $100 billion--obsolete" (20:71). The defender will be forced to expend extra time, effort, and money to create a wide variety of systems capable of detecting and destroying low observable vehicles. Because of this leverage, stealth technology must be protected with the highest degree of security.

However, the secrecy in which stealth technology is cloaked has fostered greater than normal public curiosity, technical interest, and romantic appeal. How many readers marveled at the ease with which Tom Clancy's stealth attack fighter, the F-19 Ghostrider, wiped out the Soviet AWACS fleet in Red Storm Rising?(2:162-165) Articles discussing the pros and cons of stealth technology appear in magazines ranging from the technical Aviation Week and Space Technology to the non-technical Popular Mechanics. The latter even includes stealth aircraft fold-outs and posters (15:70). The Testors Corporation, a model airplane company famous for its accurate models, claims it has an "authentic 1/72 scale F-19 Stealth fighter [which] is based upon years of extensive research" (42:-). This attention highlights the rising awareness of a technology that could soon revolutionize air combat.

The American public's awareness of a new technology is not the focus of this article. Rather, the purpose is to make the

American public, and in particular American military planners, cognizant of a strong Soviet intent to obtain and apply this revolutionary technology. More specifically, this article will show the Soviets intend to develop and deploy systems using stealth technology.

To accomplish this, the primary areas of concern in stealth technology will first be examined and definitions of its major components will be presented. Once the concept of stealth technology is understood, current Soviet aerospace doctrine will be reviewed and an assessment made as to the applicability of stealth technology to this doctrine. A review of some of the current open-source literature should provide an indication of the depth of the Soviet technology base and its capability to produce a stealth vehicle. Finally, an updated recap of the Soviet "Mirror Policy", a concept used to fill technology gaps by copying Western systems or ideas, will show this policy is still a valid component of Soviet military development.

Chapter Two

STEALTH TECHNOLOGY

Stealth technology is not defined by just one technology. Instead, it is comprised of several technologies which influence the detection of the vehicle. The four primary areas of concern in the design of a low observables vehicle are its acoustical, optical, infra-red, and electronic signatures. The theoretical goal of any stealth designer would be to make the aircraft impervious to detection by eliminating these signatures.

However, General Lawrence Skantze, past commander of Air Force Systems Command, noted, "We've never contended that stealthy means invisible. It means difficult to detect--and more difficult to track."(9:22) The detection problem will be so difficult that normal methods of bringing weapons to bear against this type of vehicle will be rendered ineffective. Thus, the stealth designer is faced with minimizing these aircraft signatures consistent with the aircraft mission.

ACOUSTIC SIGNATURE

The acoustic or noise signature of most aircraft is comprised of two parts, wind noise and engine noise. Movement of an aircraft through the air produces a characteristic signature, and the design of that vehicle can affect that signature (7:54). Automobile designers attempt to decrease the turbulent airflow around a car to reduce drag and lower the interior sound level. In a similar fashion, the aerodynamic engineer must also design his vehicle to slip through the air. However, the wind noise component is not the predominant acoustic signature of an aircraft.

The primary contributor to the acoustic signature of an aircraft, as most people who live around airports know, is engine noise. Much open-source literature can be read concerning the "noise footprint" of several of today's commercial aircraft. Most engine noise is a result of two causes: engine growl and engine roar (41:70).

Engine growl, the smallest contributor to the noise footprint, is generated by the compressor and turbine sections of the engine. It is the whining noise most often heard when a jet

aircraft taxis by. Burying the engines deep within the aircraft structure is one method of reducing this noise source (7:54).

The second and largest component, engine roar, is caused by the shearing effect which occurs when the high temperature, high velocity jet exhaust contacts the cooler ambient air. The distinct change in aircraft noise levels when the pilot selects afterburner is directly attributable to this phenomena (3:213). Lowering the engine exhaust gas temperature and more rapid mixing of the engine exhaust with the ambient air can cause a reduction of the engine noise. Also, the use of medium to high-bypass turbofan engines and some form of louvered exhaust system will probably produce a large reduction in engine roar (41:70).

OPTICAL SIGNATURE

Although there are not many threat systems using acoustics as their primary detection source, there are many that rely on optical tracking aids. Optical trackers on many surface-to-air missile (SAM) systems are used against low flying targets when background clutter is too high for radar tracking (13:58). Even a simple system, such as the fighter pilot's eye ball, is heavily dependent upon the aircraft's visual signature. Thus, the optical signature of an aircraft plays an important role in aircraft survivability.

As Bill Sweetman, author of Stealth Aircraft, states, "avoiding detection by the naked eye or tracking by electro-optical systems may be more difficult" (7:54) than avoiding acoustical detection. Besides operating the aircraft at night, there are certain design enhancements that might alter its optical signature. Better profile design, the use of smokeless engines and passive and active camouflage are some of these techniques.

Physical size and layout of the aircraft structure can enhance the visual signature of a vehicle. The Northrop T-38 or the MIG-21 are both quite small aircraft and are hard to detect with the unaided eye. With the proper profile, even large aircraft become hard to detect visually. A classic example of a large aircraft with a small visual signature was the YB-49 flying wing bomber. Old films of the Northrop aircraft "show how the aircraft virtually disappears from view as it turns head-on to the camera" (7:54). However, the dense trail of black smoke from the eight J35 engines often gave it away.

Today's engines, such as the General Electric F404, and denser fuels contribute to more complete combustion (7:54). As a result, most modern fighters no longer have the characteristic brown-black exhaust trail that was most often seen before the aircraft was.

Camouflage paint on aircraft has existed since the end of WWI and simply involves painting the aircraft with a scheme that is conducive to the operating environment. Most camouflage schemes attempt to make detection on or near the ground difficult (7:54). Still others try to make detection in the air combat environment difficult. One paint scheme, that of artist Keith Ferris, even sought to make attitude detection difficult. His scheme appeared on four F-15 aircraft in the late 1970s and became know as the Ferris Attitude Deception scheme. Ferris felt painting the bottom of the aircraft like the top, to include painting false canopies, would create a more difficult attitude identification task (6:97).

An even more aggressive approach to reducing the optical signature is the concept of active camouflage. This principle states the more closely the aircraft brightness matches the surrounding background, the more difficult will be optical detection (41:70). This camouflage technique uses an on board set of sensors coupled with a lighting system to reduce the lighting differential between the background and the aircraft (7:54). Based upon sensor input, the lighting system illuminates the aircraft until the aircraft brightness matches that of the surrounding background (41:70). Such a system might not fool the human eye, but it might foil detection by an optical tracker on a SAM system (7:54).

INFRA-RED SIGNATURE

Heated objects radiate infra-red (IR) energy. The object's temperature determines the characteristics of that radiation. As the temperature of an object increases, the overall bandwidth of transmitted energy increases. Additionally, as the temperature increases, the peak intensity of the energy spectrum shifts to shorter and shorter wavelengths (39:68).

The infra-red, or thermal, signature is second only to radar in aircraft detection capability. Like radar, the IR signature of an aircraft can be detected beyond visual range. The atmosphere transmits energy at the wavelengths of light very inefficiently. Although the atmosphere has similar effects on the IR spectrum, there are two bands, or windows, of IR wavelengths not affected in this manner. They are located at the 3-4 micron and 8-12 micron region in the IR spectrum (39:68). (A micron is a unit of measurement and is one millionth of a meter, or 10^{-6} meters).

The importance of these bands is that all three major components of an aircraft IR signature emit energy in these bands. These three major components of the IR signature are as

follows: the heat generated from the jet engine hot metal, hot exhaust air from the engine and other sources like the avionics, and the heat generated from air friction by moving through the air (7:52).

Obscuring the hot metal parts of the engine from as many viewing angles as possible is probably the current trend in reducing this strong source of IR radiation. Installing the engines deep within the aircraft and redesigning the exhaust nozzles may help reduce the IR signature (7:53). The use of two-dimensional (2-D) nozzles, which are currently under development for the ATF (12:66), will probably restrict the rear view of the engine to a very narrow angle.

Rapid mixing of cooler air with that of the engine and avionics exhausts should significantly reduce the intensity of this IR component. The use of high-bypass turbofan engines is probably ideal in the design of a low observables vehicle from an IR viewpoint. Because it uses large quantities of ambient air to produce its thrust, it has a lower IR signature. However, due to its relatively large size, it would be difficult to hide it within the airframe. Thus, medium-bypass turbofan engines coupled with integral hot/cold flow mixers could solve this IR problem (7:53).

One proposed method of lowering the IR energy emitted caused by airframe friction is to use the on board fuel as a heat sink. The heat from air friction, normally emitted in the 8-12 micron range (26:41), could be absorbed by the cooler fuel in contact with the skin of the aircraft. The heated fuel could release the absorbed energy through a heat exchanger into the engine exhaust, or it could be burned in its pre-heated state. Pre-heating the fuel in this manner leads to better combustion properties (7:53).

ELECTRONIC SIGNATURE

The aircraft's electronic signature is probably most important to aircraft survivability. The majority of anti-aircraft systems in the world today are radar guided. Reduction of this signature must occur before a low observable vehicle can work.

The electronic signature of an aircraft is primarily composed of two basic types of signals: those emanating from the aircraft itself and those reflected by the aircraft from ground or airborne transmitters. Controlling the electronic emissions will solve the first problem. Reducing the amount of energy reflected to a radar receiver will solve the second.

Electronic Emission

The degree to which signals emanate from the aircraft greatly affects its detection range by surveillance systems. At night time, an oncoming car's headlights reveal its position at long distances. However, if the oncoming car's headlights are not on, detection range is greatly reduced when only the headlights of our car illuminate the road ahead. The same analogy applies to the electronic systems on board an aircraft, especially radar.

Current aircraft are heavily dependent upon radar for several tasks ranging from navigation and target acquisition to terrain following. Reducing the dependence upon this system and increasing the use of more passive devices is required to lower future electronic signatures. A strong effort is being made on the ATF to rely heavily on passive detection systems (26:41).

Increased accuracy of inertial navigation systems (INS) and the use of forward looking infra-red (FLIR) systems will enhance the navigation and target acquisition problems encountered without radar. The development of such systems as low probability of intercept (LPI) radar systems will allow the use of radar but at a much reduced chance of detection (10:27). Technology is now introducing the laser radar which will be much less susceptible to interception in a hostile environment (29:124).

Radar Signature

To increase the survivability of an aircraft in the electromagnetic environment, the designer has control of only one variable, the radar signature, or radar cross section. The radar cross section (RCS) is a relative measurement that describes the amount of energy intercepted and then reflected by a target. To calculate an object's RCS, the energy directly reflected by an object is measured. Then, the projected area of a sphere required to return the same amount of energy is calculated. The size of that sphere is the object's RCS (8:61).

RCS generally has units of square meters (m^2). However, since electrical engineers developed radars, RCS engineers often use an electrical engineering unit, the dBsm, as units for RCS. In common engineering usage, the dB is used to express any ratio. The exact equation for defining this unit can be found in any radar design handbook (8:145).

In this case, it's the ratio of the object's RCS to a one square meter sphere. Table 1 presents conversions between RCS measured in square meters to that in dBsm along with RCS values of some common targets.

dBsm	m²	Target[1]	Frequency[2]
60	1,000,000	Liberty Class Naval Ship (broadside)	2.8 Ghz
50	100,000	Liberty Class Naval Ship (head on)	2.8 GHz
40	10,000		
30	1,000	B-52 (head on)	
20	100	B-1A (head on)	
14	25	F-15 (broadside)	
10	10	B-1B (head on)	
0	1		
-10	0.1		
-12	0.06	Large Adult Duck	0.4 GHz
-20	0.01	Speculated ATF Goal	
-30	0.001	Blue Winged Locust (broadside)	9.4 GHz
-40	0.0001	Honey Bee Worker (broadside)	9.4 GHz

[1]Source for targets with listed frequency (4:184-185)
Source for targets without listed frequency (7:34)

[2]Measured in Giga Hertz (1 billion cycles/sec)

Table 1. RCS Conversion and Target Size

The RCS of an aircraft is generally described using four variables: the amplitude of the return to the emitter, the aspect angle (azimuth) to the emitter, the look angle (elevation) to the emitter, and the frequency of the emitter (4:156). A simplistic representation of an aircraft's RCS (in dBsm units) is

depicted in Figure 1 for one look angle and one frequency. Note that the RCS varies as azimuth angle to the emitter changes. Different values of RCS would be obtained at other look angles or emitter frequencies (4:182).

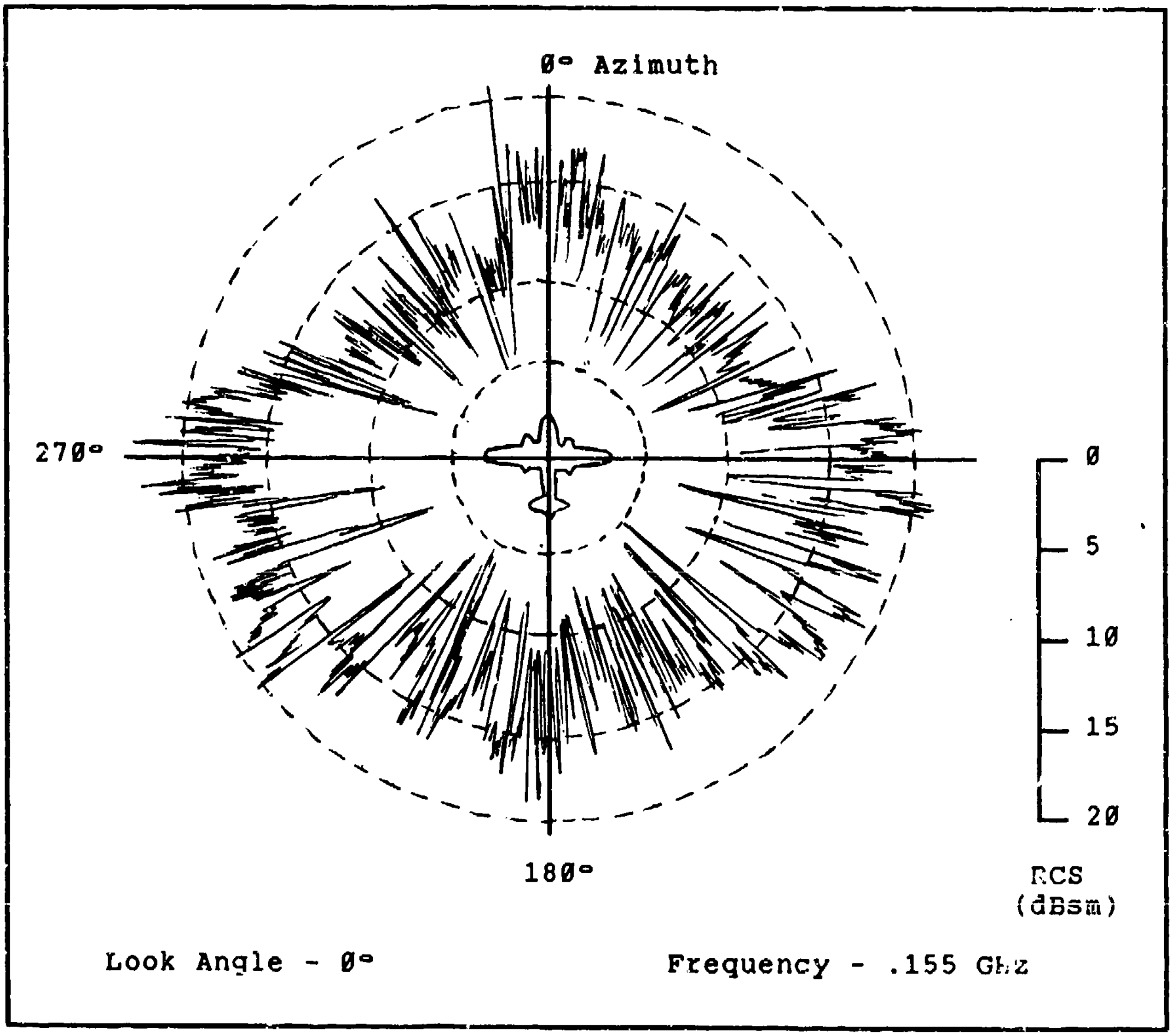

Figure 1. Aircraft RCS Plot

Combining the RCS values for all look angles, azimuths, and frequencies results in a family of three-dimensional shapes, one for each frequency of interest. As one textbook put it, each of these complex shapes can be described as being similar to "a porcupine, with strong radar reflections as quills."(7:64) The porcupine's quills or spikes get fatter or thinner, shorter or longer, depending upon the strength of the radar return (4:192).

The strength of these radar spikes directly affects the detection range of the aircraft. The objective of the design engineer is to control or reduce the number, size and direction of these spikes.

The first task a designer must undertake in accomplishing radar cross section reduction (RCSR) is to identify the aircraft components creating these spikes or flare spots. Flare spots are locations on an aircraft that represent the dominant radar returns. Some of the major sources of radar return are the

> jet engine intake and exhaust ducts, the leading and trailing edges of airfoils, the radar antenna, external stores, the cockpit canopy, and assorted protuberances in the aircraft, such as airspeed indicators [probes] and communications antennas . . . Near the broadside aspects, the fuselage, engine pods, external fuel tanks, and the vertical stabilizer are large echo sources (4:197).

The design engineer must also determine the type of radar reflection creating the flare spot. RCSR is accomplished when the designer is able to control the influence of four major components of radar reflections: specular returns, creeping waves, traveling waves, and resonances (4:160-177). Specular returns are essentially governed by the physics of optics and are similar to light bouncing off a mirror. Creeping waves occur when incident radar waves hit spherical- or cylindrical-shaped objects. The wave circles the rear of the object and is launched back to the emitter (4:162). Traveling waves occur when radar waves strike flat plates at near edge-on incidence. The wave induces an electrical current that builds up in the surface. Unless the current is absorbed at the end of the surface or flows around some smooth termination, the wave is reflected back to the emitter (4:166). The final type of reflection, resonance, occurs when objects on the aircraft become tuners (amplifiers) for the wavelength of the radar waves striking them (4:168).

Once the design engineer has determined the source and composition of the strong radar reflections, the proper RCSR technique can be applied. There are currently four major RCSR techniques in use: shaping, radar absortion material, passive cancellation, and active cancellation (4:190).

Shaping. The main objective of shaping is to "orient the target surfaces and edges so as to deflect the reflected energy in directions away from the radar" (4:190). However, this cannot usually be done for all aspect and look angles. Shaping usually shifts the regions of higher radar returns from one sector to another. The RCS reduction achieved in one area is accompanied by an RCS enhancement in another (4:191).

A designer can best exploit the advantages of shaping if threat sectors are established. For instance, if the nose sector is the most prominent threat sector, then the designer can concentrate on this area. Typically, a large cross section can be shifted out of the forward sector toward the broadside sectors (4:191). This shaping technique may apply in elevation angle also. Placement of engine inlets on top of the fuselage may be advantageous if the aircraft will not be observed from above (4:191).

Another shaping technique called screening can also reduce the radar returns from engine inlets and aircraft canopies (4:211). The use of screening is present in the door of the common household microwave oven. A wire mesh in the glass door appears in electrical terms as a solid reflective wall because the holes in the mesh are smaller than the radar wavelength in use. However, an observer can see the food cooking inside the oven because the mesh doesn't obstruct light. This same technique can keep incident radar waves out of cavities, like engine inlets or cockpits, while letting in air or light (4:211).

Coating the inside of the canopy with a translucent, metallic film of gold or indium tin-oxide is an alternate form of screening for the cockpit (7:44). It not only keeps incident radar waves out but electronic emissions from cathode ray tubes and computers in (7:44-45).

The design of the SR-71 was probably an early attempt in the use of RCSR techniques. In listing a generic collection of shaping options in the text, Radar Cross Section, the authors perfectly describe the SR-71.

> The return from the edge presented by the [fuselage] chine is considerably lower than that of the generic fuselage . . . we see the advantages of a sharp, straight leading edge with a long taper aft, rounded corners, and a flat underbody. In addition, the vertical fins are canted inward to reduce their broadside contribution and the nose is brought to a sharp point (4:215).

Radar Absorbing Material. When shaping is not enough or when a designer desires to absorb as much as possible the redirected energy, radar absorbing material (RAM) is useful. Radar energy may be absorbed by an ohmic loss process similar to the way a resistor dissipates heat in an electric circuit (4:191). The energy loss caused by RAM is actually the conversion of microwave energy into heat. Although the RAM never absorbs enough energy to feel hot, this is the actual method of operation (4:191). Two types of materials have commonly been used in developing RAM.

The first material used was carbon because of its poor electric conductivity. Carbon, which is typically used to create resistors, is widely used in the construction of indoor microwave anechoic chambers and experimental and diagnostic work. The cuniforms often seen in anechoic chambers are made of carbon impregnated material. However, because they are bulky and fragile, carbon-based RAMs do not work in operational environments (4:191-192).

The second type of RAM is based upon magnetic absorbers. Every electro-mangnetic wave (radar wave) has an electric field and an accompanying magnetic field (8:2). Removing energy from either of these fields will dissipate the energy of the radar wave. Magnetic absorbers, used more often in the operational environment, are typically constructed using iron or iron-oxide (ferrite) compounds (4:192). The energy loss due to the material comes about when the absorber molecular structure tries to align itself with the passing magnetic field. Work is done on the structure by the field and energy is dissipated. Most absorbers are fairly efficient but are typically very heavy because of their iron content (4:192).

Passive Cancellation. Passive cancellation is also known as impedance loading. Impedance is another form of resistance and is often used when matching antennas to microwave transmitters. The basic principle is to create an echo source whose amplitude and phase can be adjusted to cancel another source. Typically, a cavity is machined into a body, and the "size and shape of the interior cavity can be designed to present an optimum impedance at the aperture" (4:192). However, this technique has never proven useful in an operational environment because of the large number of frequencies impacting aircraft and the large number of echo sources on a vehicle (4:192).

Active Cancellation. Active cancellation, also known as active impedance loading, is even more ambitious in scope than passive loading. The process of active cancellation requires large amounts of computer power. The target aircraft must emit radiation whose amplitude and phase exactly cancel the reflected energy it sends back to a threat radar (4:192).

The implications of this process are enormous. The aircraft carrying such a system must sense parameters such as the angle of arrival, the intensity of the signal, the frequency and the waveform of the arriving radar wave. It must also know what its RCS looks like for that particular frequency and arrival angle. Finally, it must be fast enough to accomplish all the above tasks in a timely manner such that the receiving threat radar accepts the input as true data (4:192).

Chapter Three

SOVIET DOCTRINE

Would current Soviet doctrine support the use of a low observables vehicle? Some would simply argue the answer to this issue is an unequivocal yes based on the Soviets' keen interest in similar technology in the submarine world. Why wouldn't the same Soviet doctrine that dictates the need to develop anechoic tiles and quieter propellers for submarines (11:26) also require the immediate need for stealthy fighters and bombers?

Others, like Bill Sweetman, author of Stealth Aircraft, argue that the application of stealth technology in the Soviet system is a radical break in the Soviet pattern of dealing with problems (7:93). He contends that the Soviet Union will probably lag the United States in the development of low observables technology. This is primarily because of the centrally controlled, hierarchical system by which it designs and builds aircraft (7:93).

The answer to this issue probably lies somewhere between these two extremes. Through a review of the Soviet approach to the formation of doctrine, this section will show how Soviet doctrine and the subordinate levels of military thought support the development and use of a low observables aircraft.

LAWS OF WAR

The Soviet approach to doctrine development is primarily scientific in nature. Basic to the understanding of Soviet doctrine is the unique, Marxist belief the historical process is governed by a set of scientific, discoverable laws (1:5). This belief is similar in concept to the fact that laws of nature govern all natural processes.

The Soviets believe war is a social phenomenon governed by a unique set of laws, the laws of war, which express its special nature (1:6). The nature of war, according to the Soviet view, is a function of three variables: ideology, history, and technology (1:6). The Marxist-Leninist ideology provides the moral factor for the people and the armies of the state. History provides the testing grounds or the laboratory for the proof of all relationships. Technology is merely a physical tool to be

used to its fullest potential (1:6). Even at this most basic level of Soviet beliefs, the development of stealth technology is warranted.

The Soviets believe military success comes from the proper application of these laws. Failure to follow the Communist ideology, failure to comprehend the lessons of history, and failure to develop to the fullest the tools of technology will result in disaster. In essence, "the laws of war determine the course and outcome of war" (1:6).

MILITARY DOCTRINE

The set of six laws of war outlined in the latest version of the Soviet Military Encyclopedia are general in nature. Consequently, they require much interpretation and explanation before becoming practical at the operational level (1:11). The Communist Party of the Soviet Union (CPSU) provides this elaboration. This elaboration becomes military doctrine and is the military expression of the political party of the CPSU (5:23).

One of the key results of this interpretation is Soviet military doctrine requires Soviet armed forces be equipped with the newest weapons and technology possible (1:14). The Soviets believe this type of development effort will prepare the people and its armies against the enemies of the state. General Major S. N. Kozlov, the author of Officer's Handbook, quotes V.I. Lenin as saying, "It is a crime to undertake war with a better prepared [or equipped] opponent" (1:14). The development of stealth technology is almost mandated at this level of Soviet doctrine. In the strictest interpretation, if an opponent has developed stealth technology, it would be a punishable offense not to acquire a similar Soviet capability.

Soviet military doctrine based on historical studies proclaims that the offense is the decisive approach to victory on the battlefield. Any means of warfare that favors the offense will be the preferred mode (1:15). Soviet dedication to the offense has often been quoted the justification for development of a Soviet navy as a modern means of attack from the oceans (1:15). It could also provide for the development of stealth technology as a modern means of offensive air attack. What is a better way to carry the war to the aggressor than to wage the air battle deep within the enemy's territory? This is the primary mission behind the design of the USAF ATF (27:70), but it could just as well be the design goal of the Soviet stealth fighter.

MILITARY SCIENCE

The lower levels of the Soviet approach to armed conflict provide the greatest support for the development of low observables technology. Military Science is the Soviet term used for the aggregate knowledge in the conduct of war (5:23). It is the product of many years of experience, scientific and historical research, and dedicated testing (5:23). Although this general field is comprised of six parts, military technology and military art are directly pertinent to low observables technology development.

Military Technology

This particular area of study groups together the military applications of various technologies and physical sciences. It includes scientific investigation into new technologies and develops means to produce equipment for the armed forces (1:22). This field of study provides an avenue for the introduction of new technology into the laws of armed conflict and military doctrine.

Far from being a system veiled in mystery, the Soviet decision-making structure is "extremely logical, precise, and systematic" (1:5). This approach to problem solving "forces the careful analysis and implementation of new ideas, and defines controversial and significant problems" (1:34). Such a new and controversial idea would be the design of low observables technology vehicles. From a conceptual viewpoint, it is not unlikely the Soviets are conducting scientific investigations into the field of low observables technology as well as means to produce such technology.

Military Art

Probably the most important component of military science is the field of military art. Military art studies the actual forms and methods of armed conflict. The outputs of this study are the basic principles of military art, of which eleven are contained in Volume six of the Soviet Military Encyclopedia (1:23). Two of these principles have direct application to the development of stealth technology.

The first principle deals with the requirement of high military preparedness for the fulfillment of missions (1:23). Preparedness, in the Soviet sense, is measured by two variables. One is the need for a strong, standing military force. The other, and probably most important, is that chance should play very little in the outcome of the war (1:23).

To decrease the impact of chance, the Soviets have developed a complex set of algorithms. Based ultimately on the laws of

war, these algorithms factor in all disciplines of military science to aid the military planner in his decision making process (1:94). One of the probable inputs to these algorithms is the effective combat power of the Soviet weapons used. This input is used to help in the determination of the correlation of forces, or combat superiority (1:91-92). The use of a stealth aircraft that would render defenses useless would probably have considerable impact on a commander's correlation of forces calculations.

The second important principle applicable to the development and deployment of low observables technology is the principle of surprise. Soviet historical studies continually show the significance of surprise in the outcome of war (34:15). Using stealth vehicles would probably increase the chances the opposing forces would not detect in sufficient time the numbers, types, and tactics of Soviet aircraft engaged in battle. Late detection by opposing forces would also provide Soviet air forces the chance to regain the initiative.

The use of jamming in support of ingressing stealth aircraft would also insure the element of surprise. Aircraft with lower RCS values do not need as much jamming support from ground or airborne sources to cover their ingress or egress routes (28:70). Given the current level of Soviet radio electronic combat (REC) capability (19:38-42), the addition of stealth aircraft used in conjunction with jammers would be a formidable force.

Current Soviet tactical writings reflect these trends toward the use of low observables technology in the design of aircraft. Colonels Y. Kislyakov and V. Dubrov in their four part series, "New Features of Air Combat", call not only for new tactics for third-generation fighter aircraft but also suggest the use of reduced radar cross sections and thermal signatures. They contend the use of low observables technology will reverse the downward trend in aircraft survivability (24:295). They speak specifically about the advantage of surprise due to reduced detection ranges. Additionally, they mention the enhancement value stealth would play on the factors of shock, fire power and maneuver (24:295).

Support for the development and deployment of low observables technology permeates all levels of Soviet doctrine and military thinking. From the basic concepts of Marxist-Leninst doctrine to the writings on military art at the operational and tactical level, there exists a fundamental need for the use of stealth technology. Next, current Soviet technology will be examined to determine if a capability for development exists.

Chapter Four

SOVIET TECHNOLOGY

As one author noted, "If information on the ATF is elusive because much falls into 'black' programs, then information on Soviet development plans must fall into a black hole, glasnost notwithstanding" (36:89). However, the overall picture is not quite that dark. Some evidence indicates the Soviets are making a concerted effort to develop or obtain stealth technology.

Many of these confirmations come from high US government officials. The late CIA Director, William Casey, in a briefing to the Senate Armed Services Committee in January 1986 stated, "We know that the Soviets are working to acquire the technology to develop aircraft and cruise missiles employing stealth features" (14:20). Secretary of Defense Caspar Weinberger stated in Soviet Military Power 1987 that "evidence suggests the Soviets have made progress in developing aircraft that may have a low-observable radar signature" (40:106).

More recently the Air Force has started to address the needs of future fire control systems to handle the impact of Soviet stealth aircraft (9:45). In particular the contracts awarded by the Air Force in August 1987 were to contain risk assessments addressing technology projection and Soviet airframe observability (9:45).

A review of many of the open-source documents concerning stealth technology reveals potential increased Soviet capabilities in this area. Some of these areas, such as the use of shaping and RAM, the development of key composite materials and the increased use of passive detection systems, are discussed below.

SHAPING

Several articles indicate that the Soviets have an increased awareness of the importance of aircraft shaping in the initial stages of design. One article, "New Features of Air Combat," indicates many efforts are being made to reduce the RCS of future aircraft (24:296). In particular, this article noted the greatest radar reflections are produced by

air intakes, dish antennas located in the nose fairing, and the cockpit canopy--when radar-painted from the front; wing-fuselage joints, the tail assembly, and external ordnance-mount pylons--when radar-painted from abeam (24:296).

This list contains some of the primary flare spots discussed earlier that must be controlled by shaping or other RCSR techniques before any significant reduction in signatures occurs.

Additionally, the Soviets have shown an increased appreciation for the use of conformal stores in an attempt to reduce RCS. They have indicated an awareness for the additional requirements RCSR has not only on the placement of stores but also on their release or launch (23:33). One article even referenced a Northrop developed air cylinder catapult system to reduce the aircraft RCS after releasing weapons (23:33).

Further efforts at RCSR of engine returns may be present on the new MIG-29 FULCRUM fighter. The longitudinal divergence of the engine nacelles could be an attempt to partially mask the Doppler return from the moving compressor blades. Hiding the compressor blades deep within S-shaped inlets is an acceptable form of shaping that could reduce the RCS of the vehicle. There is also a reported use of screening in the form of streamlined baffles in the intakes of other Soviet aircraft (37:55).

Additionally, some evidence suggests the Soviets have probably made progress in reducing the radar return from the canopy. A gold colored tint in the canopy of the MIG-31 FOXHOUND could indicate they have developed a method to coat the canopy with a metallic film (37:56).

On the more theoretical side, there have been several publications in scientific journals concerning the theory of radar echoes of simple shapes. These studies have conducted research on objects with both metal and dielectrical surfaces (38:3). Most of these studies do not give any indication to the Soviet design philosophy concerning shaping. However, these data could potentially yield valuable RCS prediction codes that might aid in any future RCSR projects (38:3).

RADAR ABSORBING MATERIAL

Most of the evidence that the Soviets are making progress in the development of RAM is circumstantial. Several readings properly indicate the use of RAM as a secondary RCSR technique to shaping (38:3). Others detail how RAM application in addition to shaping can reduce flare spot returns from areas such as junction points like hatches and joints (25:368).

The Soviets also have long realized the importance of using iron-oxide compounds or ferrites in obtaining stealth qualities (37:55). An increased number of RAM related papers have appeared in the major scientific journals (38:4). Additionally, the recent shifting of scientists from optics to RAM development highlights the Soviets' intense effort to develop this substance (38:4). Many of the laws of optics not only stipulate the requirements for proper aircraft shaping but also govern the laws for development of the absorption properties of RAM (38:4).

Even if the Soviets are lagging in the development of RAM, several types of RAM are presently available on the open market from countries like Japan (37:56). Reverse-engineering, a concept the Soviets are quite familiar with, could possibly yield design techniques for Soviet-made RAM.

The first probable use of Soviet RAM may have already occurred. A Norwegian photograph taken of the SU-27 FLANKER revealed what appeared to be darkened regions inside the engine intakes. Several interpretations of these regions have been as possible RAM inside the inlet to reduce reflections from the compressor face (18:545).

RELATED TECHNOLOGIES

Composites

With the introduction of the AN-124 CONDOR at the 1985 Paris Air Show, the Soviets made a significant jump in the use of composite materials in aircraft. Many of the load bearing members were made of graphite/epoxy materials. Overall, roughly six tons of composite materials were used on the aircraft's structures and surfaces (37:55). The importance of this development is these types of structures are noted for their non-conductive qualities. In fact, construction of the ATF will also use composite materials (33:57).

The Soviets have also made progress in the development of engine components using advanced materials. Secretary Weinberger noted the Soviets are quite advanced in their research and development efforts in the areas of ceramics and exotic composites (40:114). In particular, the proper use of ceramic turbine components could result in RCS reductions (37:57).

Electronic Emissions

The suppression of electronic emissions is also another area of intense Soviet research. As discussed earlier, the use of LPI radars, laser altimeters and velocimeters, and laser radars would probably decrease the emission signature of a stealth vehicle.

The Soviets see laser devices as prime replacements for their current radar systems (37:56).

Additionally, the Soviets have had a long standing belief in the use of passive detection systems, particularly in the IR field. Most recently, the Soviets appear to have recognized the importance of stealth tactics by equipping their new fighter weapon systems with an advanced Infra-Red Search and Tracking (IRST) system (31:60). Again, by comparison, much time and effort has been put into the development of a US IRST for use on the ATF as one of its primary weapon sensors (25:72).

Even this brief review of open source publications has revealed a concerted effort on the Soviet's part to develop a foundation in stealth technology. They have concluded the selection of the proper shape is the primary means of controlling RCS. Additionally, the Soviets have generated a considerable data base for the development of RAM substances. They also appear to be knowledgeable in the proper application of RAM to reduce the effects of flare spots. The Soviets are continueing to lead the world in the development of exotic ceramic materials necesssary for fighter engines of the future, especially stealth fighters. Finally, they have a long research and development effort in the effective use of passive detection systems so vital to the operation of future stealth fighters.

Chapter Five

MIRROR POLICY

Even if Soviet stealth technology does not currently exist, one design policy still confronts the West, the Mirror Policy. This concept has existed since the end of World War II. Since that time, it has been a constant component of Soviet design philosophy (17:122).

The concept centers around the Soviet doctrine discussed earlier of maintaining a Soviet army equipped with the latest technology has to offer. When the Soviets were lacking in any particular technological or operational sector, they tried to copy, as closely as possible, the Western concepts and ideas (17:122).

This use of the mirror policy does not mean the Soviets have to get involved with the illegitimate transfer of technology. In the case of the SU-25 FROGFOOT, the Soviets practically copied the USAF specifications for the close air support competition. The probable reason the FROGFOOT doesn't look like the A-10 THUNDERBOLT is they used the Northrop entry, the A-9, as a model (21:-).

More often than not, however, this policy centers around the illegal transfer of Western technology. Defense Secretary Weinberger's introduction in <u>Soviet Military Power 1987</u> even acknowledges "the theft of Western technology, required for new generations of weapons systems,"(35:27) as a well developed strategy. The recent deployment of the MIG-29 FULCRUM, which is an F-18 look-alike, appears to have involved some illegal technology transfer, particular in the radar performance area (17:127). More recently, Congressional investigators pointed out that a Northrop employee was arrested in December 1984 for attempting to sell Soviet agents "the core of the [ATB] Stealth technology."(16:3)

Figure 1 represents approximately the last thirty years of development under the mirror policy. Plotted are the years in which a US proto-typed system first flew versus the years in which the equivalent USSR proto-typed system flew. The important point about this figure is that the Soviet Union has mirrored almost every major aircraft weapon system the United States has deployed. Even if the Soviets lag US deployment of the ATF by

five years as the chart indicates, they will probably develop a stealth prototype near the turn of the century.

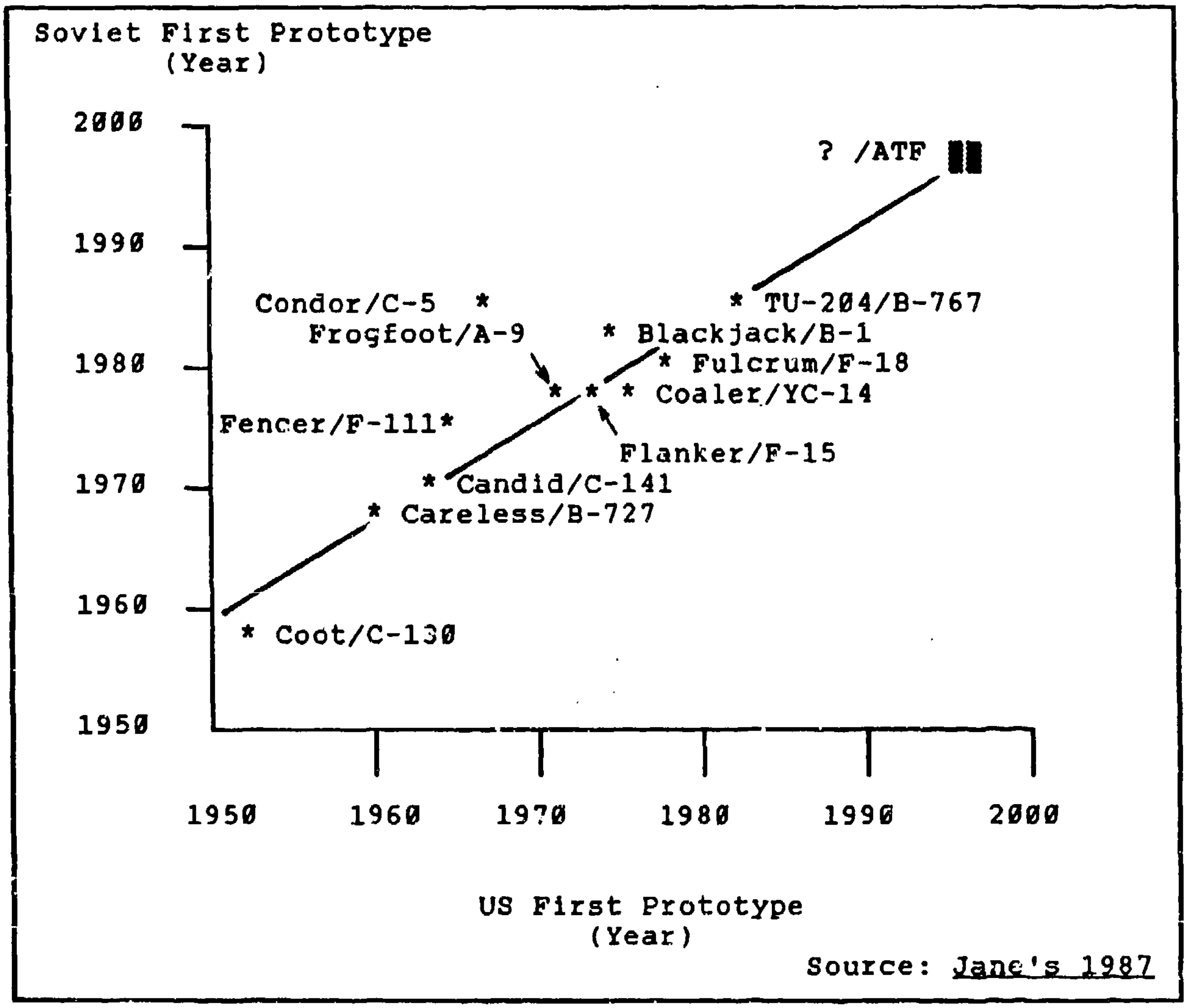

Figure 2. Soviet Mirror Policy

The significance of this mirror-imaging policy cannot be over-emphasized. The much maligned Soviet craftsmanship and production capabilities are fast approaching the higher standards of the Western world. In July 1986 General Skantze summarized to Congress that while the "US has the world's best fighters in the F-15 and F-16, the Soviets have now pulled up with similar capabilities encompassed in the MiG-29 and Su-27."(30:133)

The US is planning to develop and deploy the ATF opposite the new Soviet fighters to regain the advantage in the air

chess, will probably counter our deployment with their version of the ATF, particularly if they feel threatened in the air superiority role.

One problem remains with this chess analogy, however. According to Adm. William J. Crowe, Jr., chairmain of the US Joint Chiefs of Staff, the Soviet Union has rarely deviated from the principle he attributes to Lenin: "Quantity has a quality all its own." (22:117) He continues to state the Soviets "always err on the side of building too many rather than too few, forcing us to look constantly for ways to offset their numerical superiorities with better concepts, doctrines, technologies, leadership and personnel."(22:117) What moves will the US make in the year 2000 when the force ratio is again 3:1 in favor of the Soviets with their ATF against ours?

Chapter Six

SUMMARY

The advent of low observables technology promises to revolutionize modern aerial combat. The Soviet's defense systems will become obsolete, forcing them to spend considerable time, money and effort developing new systems. Because of this tremendous leverage, this technology is protected by the US with the highest degrees of security. However, stealth technology can become a two edged sword, particularly if the Soviets develop the capability.

Although it is a technology that is very complex and hard to master, it is a technology the Soviets strongly desire. The Soviets have the basic military doctrine capable of embracing the concept of stealth aircraft and its use to their advantage. They have demonstrated an understanding of the basic principles of stealth technology. They also have the technological capacity for producing such vehicles. If our efforts to thwart technology transfer are not successful, history shows us the development and deployment of a Soviet ATF is inevitable.

The only questions remaining are when will it be deployed and what will be its capabilities. This study has shown that the Soviets will probably start deployment of the stealth fighter near the turn of the century. Even if it's capabilities fall short of those of the US ATF, the Soviet stealth fighter produced in mass numbers will still be a formidable vehicle. The US must be prepared for the eventuality of facing the full scale version of Testors' newest model airplane kit. It's designation:

MIG-37B 'Ferret-E' Soviet Stealth Fighter.

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